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ABSTRACT

Seventy-nine college students were taught laws of logarithms via the TICCIT CAI system. Most of the students were assigned to learner control or yoked treatment groups. Students assigned to learner control groups were able to choose how many instances to study. Students assigned to yoked groups were randomly yoked to students in the learner control groups in such a way that each student in the yoked groups was required to study the same number of instances for the same amount of time as studied by his or her companion in the learner control groups. No differences in posttest performance and attitude toward the instruction occurred between the learner control and yoked groups. Thus, no evidence was provided that learner control of number of instances will accommodate individual differences in learning a rule-using task. (Author)

Learner Control of Number of Instances in a Rule-Using Task[1]

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Abstract

Seventy-nine college students were taught laws of logarithms via the TICCIT CAI system. Most of the students were assigned to learner control or yoked treatment groups. Students assigned to learner control groups were able to choose how many instances to study. Students assigned to yoked groups were randomly yoked to students in the learner control groups in such a way that each student in the yoked groups was required to study the same number of instances for the same amount of time as studied by his/her companion in the learner control groups. No differences in posttest performance and attitude toward the instruction occurred between the learner control and yoked groups. Thus, no evidence was provided that learner control of number of instances will accommodate individual differences in learning a rule-using task.

Learner Control of Number of Instances in a Rule-Using Task

In a rule-using task, an instance can be in the form of an example or a practice item. An example presents how the rule (generality) is applied to specific information. A practice item asks the student to apply the rule to given information.

Five studies have investigated learner control of the number of instances in rule-using tasks. In two of these studies (Beard, Lorton, Searle, & Atkinson, 1973; O'Neal, 1977), computer programming languages were taught with computer-assisted instruction. One of the treatments in both experiments allowed learners to examine as many practice items as they wished. Most of the remaining treatments required learners to correctly answer a specified number of practice items before permitting them to advance. No differences for posttest score and number of instances studied were found between any of the treatments.

Another study (Dean, 1969) supplied elementary school children with instruction on basic arithmetic rules. There were two treatments, a learner control and a teacher control group. Each child assigned to the learner control group decided how many arithmetic problems to work while each child in the teacher control group was told by the teacher how many problems to complete. Fourth graders in the learner control group practiced more and did better on a delayed

posttest than fourth graders in the teacher control group. Fifth graders in the learner control group practiced and scored the same as fifth graders in the teacher control group. Sixth graders in the learner control group practiced less than, but achieved the same as sixth graders in the teacher control group.

In two other studies (Walker, Axtell, Fletcher, & Merrill, 1977; Walker, & Merrill, 1978), college students were provided with computer-assisted instuction on laws of logarithms. These two experiments included a learner control treatment, in which students could view as many examples and practice items as they pleased, and three machine control treatments, in which students studied a pre-established mandatory number of instances. One machine control treatment required students to look at sixteen instances for every unit of instruction, another at eight, and another at four. Learner control students performed better on the posttest, but spent more time on instruction and saw more instances than machine control students who saw four instances per unit of instruction. Learner control students received similar posttest scores, devoted the same amount of study time, and observed nearly an equal number of instances as machine control students who were given eight instances per unit. Learner control students also scored the same as machine control students who looked at sixteen instances per instructional unit even though the learner

control students spent less time and inspected fewer instances.

The results of the five studies described above indicate that with a rule-using task there is an optimum number of instances for a given population of students to study. As students of this population study more than the optimum number of instances, the instruction becomes less efficient because more time is spent than is necessary. Such inefficiency was apparent with the sixth grade teacher control students in the Dean experiment and the machine control students who were required to see sixteen instances per unit in one of the Walker experiments. These two groups of students studied more instances than, yet scored the same as learner control students. Likewise, as students of a given population study fewer than the optimum number of instances, the instruction becomes less effective. Such ineffectiveness was noticeable with the fourth grade teacher control students in the Dean experiment and the machine control students who were required to see four instances per unit in the other Walker experiment. These two groups of students not only studied fewwer instances, but scored worse than learner control students.

The findings of the five studies further suggest that learners usually are capable of selecting the optimum number of instances for a rule-using task when provision is made for them to choose how many instances to study. Posttest

performance of the learner control groups always matched or surpassed that of groups in which the number of instances was prescribed. However, the findings provide no evidence that the optimum number of instances for a particular rule-using task varies with individual differences in learning that task and that each learner is capable of selecting his/her own optimum number of instances. Fifth grade teacher control students in the Dean study and students who were shown eight instances per unit in the Walker study performed as well as learner control students.

The sense of freedom which accompanies learner control should enhance enjoyment of the instruction. But, no affect differences were found between groups with learner control of number of instances and groups without that control. Affect differences may not have been significant because learners were allowed to control the amount of time they spent studying the instruction. Perhaps, if such control were removed, control of number of instances would appreciably influence attitude toward the instruction.

The purpose of this experiment was to test three propositions. First, learner control of number of instances will accommodate individual differences of optimum number of instances for a rule-using task when time spent studying the instruction and the number of instances are held constant. In other words, each learner with control of number of instances will select the number of instances best suited to

him/her while each learner without such control probably will receive an inappropriate number of instances for him/her. Second, even when learners are provided with far more than the population optimum number of instances, they will choose to study only the population optimum number of instances. Third, students given control of number of instances will feel better toward the instruction than students not given such control when time spent studying the instruction is held constant.

Method

Students

Seventy-nine student volunteers (58 males, 21 females; 40 freshmen, 25 sophomores, 6 juniors, 8 seniors) participated in this study. They were enrolled in an introductory algebra course at Brigham Young University. Their mean age was 21.5 years.

Apparatus

The instruction was presented via the Time-Shared Interactive Computer Control Information Television System ("MITRE Corporation," 1976). This system often is referred to as TICCIT.

Materials

A lesson on laws of logarithms was used as the rule-using task. These laws were:

1. $\log 10^x = x$
2. $\log (x \cdot y) = \log x + \log y$
3. $\log (x^p) = p \cdot \log x$

4. $\log(x/y) = \log x - \log y$

The lesson consisted of five segments. The instructional objectives of these segments appear in Figure 1.

Insert Figure 1 about here

Each segment was composed of a rule (generality), examples of the rule, and practice items of the rule. Figure 2 shows the rule, one example, and one practice item for segment three.

Insert Figure 2 about here

A posttest containing twenty logarithm problems which paralleled the practice problems in the instruction was developed. Also, an affective questionnaire with six five-point rating scales and one question was constructed. Characteristics of the instruction that were measured by the scale included interest, excitement, length, organization, clarity, and overall appeal. The question asked how many of the math class modules the student would want to be like the instructional material in the experiment.

Procedure

The experiment was conducted over three consecutive days. Students signed up for a specific two-hour period during one of these days. The students who volunteered for

the first day were randomly assigned to two treatment groups: the learner control more group (LCM) and the learner control optimum group (LCO). Students in the LCM group could choose to study up to twenty-four examples and twenty-four practice problems in every segment. Students in the LCO group could choose to study up to four examples and four practice problems in every segment. Walker and Merrill (1978), who used the same logarithm material as employed in this study, found that the population optimum number of instances to study in each segment was four examples and four practice problems. Hence, more than the population optimum number of instances was available to students in the LCM group, while only the population optimum number of instances was available to students in the LCO group.

The students who signed up for the second or third day of the experiment were randomly assigned to one of five treatment groups: the yoked many group (YM), the yoked optimum group (YO), the second learner control many group (SLCM), the second learner control optimum group (SLCO), and the control group. Students in the YM group were randomly yoked, one to one, with students in the LCM group in such a way that each student in the YM group was required to study the same number of instances in every segment of instruction as studied by his/her companion in the LCM group. Similarly, students in the YO group were randomly yoked to students in the LCO group. Thus, students in the yoked groups and first

day learner control groups observed the same total number of instances. The learner control groups only differed from the yoked groups in that the students in the learner control groups were allowed to choose the number of instances they studied whereas the students in the yoked groups were not permitted such a choice.

Students in the SLCM group received a treatment identical to that given students in the LCM group; and students in the SLCO group received a treatment identical to that given students in the LCO group. Students in the control group were administered the posttest before they were given the instruction.

Figures 3 and 4 illustrate the sequence of displays used to present each segment of the instruction. Double boxes represent timed instruction displays; single boxes, untimed direction displays; and diamonds, computer decisions.

Insert Figures 3 and 4 about here

Instruction displays presented rules, examples or practice problems. More than one instruction display was needed to present some of the rules and examples. Every practice item was composed of three displays. The first practice display described the problem. The second practice display still exhibited the problem and asked the student to type in his/her answer. The final practice display provided

correct answer feedback while continuing to show the problem and the student's response.

Each instruction display was assigned a time limit on the basis of data collected from another experiment (Strickland, Fletcher, & Merrill, Note 1) which employed the same logarithm lesson as that used in this study. The number of seconds a particular instruction display appeared on the terminal screen was indicated in the upper right-hand corner of that display. When this amount of time had elapsed, the instruction display was replaced automatically with another display by means of computer-actuated branching. Such automatic branchings are represented by the solid arrows in Figures 3 and 4.

Direction displays requested students to press certain buttons or to raise their hands. As shown in Figure 3, students in learner control groups were given direction displays which provided them with the option of looking at as many instances as they pleased within the maximum number of examples and practice problems. Conversely, Figure 4 shows that students in yoked groups were given direction displays that did not allow them to make any decisions regarding which button to push next.

Learner control groups also differed from yoked groups with respect to the computer decisions. In learner control groups, the computer decided whether the maximum number of examples or practice items had been presented to each

student. But, in yoked groups, the computer decided whether the same number of examples or practice items had been presented to each student as had previously been studied by his/her companion in one of the learner control groups.

If a student pressed a button that he/she was not directed to press, a display would appear asking the student to raise his/her hand so that one of the experimenters could remedy the mistake.

Prior to receiving the lesson material, students were presented a brief segment containing directions which described the characteristics of rules, examples, and practice problems; the sequence and format of the instructional presentation; and the time limitations. Upon completing the lesson material, students responded to the affective questionnaire and posttest. Both the questionnaire and posttest were administered off-line and had no time restrictions.

Results

A one-way ANOVA with planned orthogonal contrasts was performed on the posttest score data for all the treatments. A two-way ANOVA was performed on the posttest and questionnaire data of the LCO, LCM, YO, and YM groups. Another two-way ANOVA was conducted on each dependent measure of the LCO, LCM, SLCO, and SLCM groups. The means and standard deviations for each treatment group on each dependent measure are reported in Table 1.

Insert Table 1 about here

Posttest Score

On the posttest, the instructed treatment groups obviously surpassed the control group whose members did not answer any test items correctly, $F = 116.9$ (1,72), $p < .0000$. Also, there was a slightly significant day of the experiment X number of instances interaction for posttest scores, $F = 4.13$ (1,41), $p < .0487$. Students in the LCM group scored better than students in the LCO group while students in the SLCM and SLCO groups scored about the same. There were no other significant main effects or interactions involving posttest score.

Questionnaire

No significant main effects or interactions occurred for any of the scales of the questionnaire, its question, or the total questionnaire score which was computed by adding up the responses of all the scales and the question.

Time Spent on Instruction

Significant main effects and interactions for time spent on instruction were not observed. However, the time spent on instruction by students in the groups which could choose to study more than the optimum number of instances (LCM and SLCM) almost significantly exceeded the time spent by students in the groups which could choose to study no more

than the optimum number of instances, F = 3.84 (1,41), $p <$ .0567.

Number of Instances

Main effects and interactions for number of instances studied by the students were not found to be significant. But, students in the groups which could choose to study more than the optimum number of instances almost studied significantly more instances than students who could choose to study no more than the optimum number of instances, F = 3.87 (1,41), $p < .0559$.

Unequal Variances

Bartlett tests were conducted for each two-way ANOVA. Unequal variances were noted in three of the analyses. For both time spent on instruction and number of instances, the availability of more than the optimum number of instances for students to study produced greater variation than the availability of only the optimum number of instances. These variance differences remained significant even when the logarithm to the base ten transformation was applied to each of the time and number of instances measurements. For posttest score, the LCO, LCM, SLCO, and SLCM groups each exhibited a unique variance. When compared with their respective means, these unequal variances seem to indicate that the students were topping out on the posttest because the largest variation was associated with the lowest posttest performance while the smallest variation was associated

with the highest posttest performance.

Discussion

The SLCO and SLCM groups were included in the study to test whether students who participated on the first day of the experiment differed from those who participated on the second or third day. The unequal posttest score variances of the LCO, LCM, SLCO, and SLCM groups and the posttest score interaction among these groups indicate that the first day students did differ somewhat from the second and third day students. This, of course, would cast doubt upon the validity of posttest score differences between the first day learner control groups and the yoked groups. However, no such differences were observed. Because the LCO, LCM, YO, and YM groups all scored about the same, the hypothesis that learner control of number of instances will accommodate individual differences of optimum number of instances for a rule-using task when time spent studying the instruction and the number of instances are held constant was not supported.

The hypothesis that even when learners are provided with far more than the population optimum number of instances, they will choose to study only the population optimum number of instances received tenuous support. The LCM and SLCM groups almost viewed significantly more instances than the LCO and SLCO groups. Furthermore, there was more variation of the number of instances studied by students in the LCM and SLCM groups than by those in the LCO and SLCO groups.

Finally, there was no support for the hypothesis that students given control of number of instances will feel better toward the instruction than students not given such control. Students responded to the questionnaire in a similar fashion regardless of the treatments to which they were assigned.

Apart from the near differences in time spent studying the instruction and in number of instances studied between students with the option of studying more than the population optimum number of instances and students with the choice of studying no more than the population optimum number of instances, the findings of this experiment parallel those of the other experiments investigating learner control of number of instances. These findings suggest that learners are capable of selecting the optimum number of instances for a rule-using task when provision is made for them to choose how many instances to study. However, there is no evidence that the optimum number of instances for a paricular rule-using task varies with individual differences in learning that task and that each learner is capable of selecting his/her own optimum number of instances. Also, learner control of number of instances does not seem to promote a greater liking toward the instruction.

Reference Note

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Table 1
Means and Standard Deviations for Each Treatment Group on Each Dependent Measure

Treatment Group	Posttest Score		Total Questionnaire Score[a]		Time Spent On Instruction		Number of Instances	
	M	SD	M	SD	M	SD	M	SD
Learner Control many (n=16)	15.31	3.53	26.62	3.77	31.73	8.77	36.56	17.33
Learner Control optimum (n-12)	16.50	2.19	26.17	4.24	26.84	5.15	27.33	7.16
Yoked many (n=16)	15.19	3.69	27.31	3.84	31.73	8.77	36.56	17.33
Yoked optimum (n=12)	13.92	3.87	27.25	[illegible]	26.84	5.15	27.33	7.16
Second Learner Control many (n= 8)	17.25	1.58	26.12	[illegible]	33.11	11.13	36.62	15.07
Second Learner Control optimum (n=9)	14.33	4.74	28.56	2.55	28.79	2.63	30.22	3.80
Control (n=6)	0.00	0.00	——	——	——	——	——	——

[a] The greater the total questionnaire score, the more positive the affect.

Figure Captions

Figure 1. Instructional objectives of each segment of instruction.

Figure 2. The rule, one example, and one practice item for segment three.

Figure 3. Sequence of computer displays for learner control treatment groups.

Figure 4. Sequence of computer displays for yoked treatment groups.

Segment	**1**	Compute common logarithms by using the Laws of Common Logarithms.
Segment	**2**	Given log m and log n, find log m/n.
Segment	**3**	Given log b, find log b^p for any real exponent p.
Segment	**4**	Given log x and log y, find log xy.
Segment	**5**	Given a power of 10, find its common logarithm. Also, given the common logarithm of a number a, write a as a power of 10.

RULE Logarithm of a Power

If x and b are real numbers, and $b > 0$,

then $\log b^x = x \cdot \log b$.

The proof is as follows:

If $\log b = p$

then $b = 10^p$

$b^x = (10^p)^x$

$= 10^{xp}$

so $\log b^x = \log 10^{xp}$

$= xp$

$= x \log b$

EXAMPLE

What is log 243?

Given: $243 = 3^5$ $\qquad \log 3 = .4771$

$\log 3^5 = 5 \log 3$

$= 5(.4771)$

$\log 243 = 2.3855$

PRACTICE

What is log 343?

Given: $343 = 7^3$ $\qquad \log 7 = .8451$

Feedback

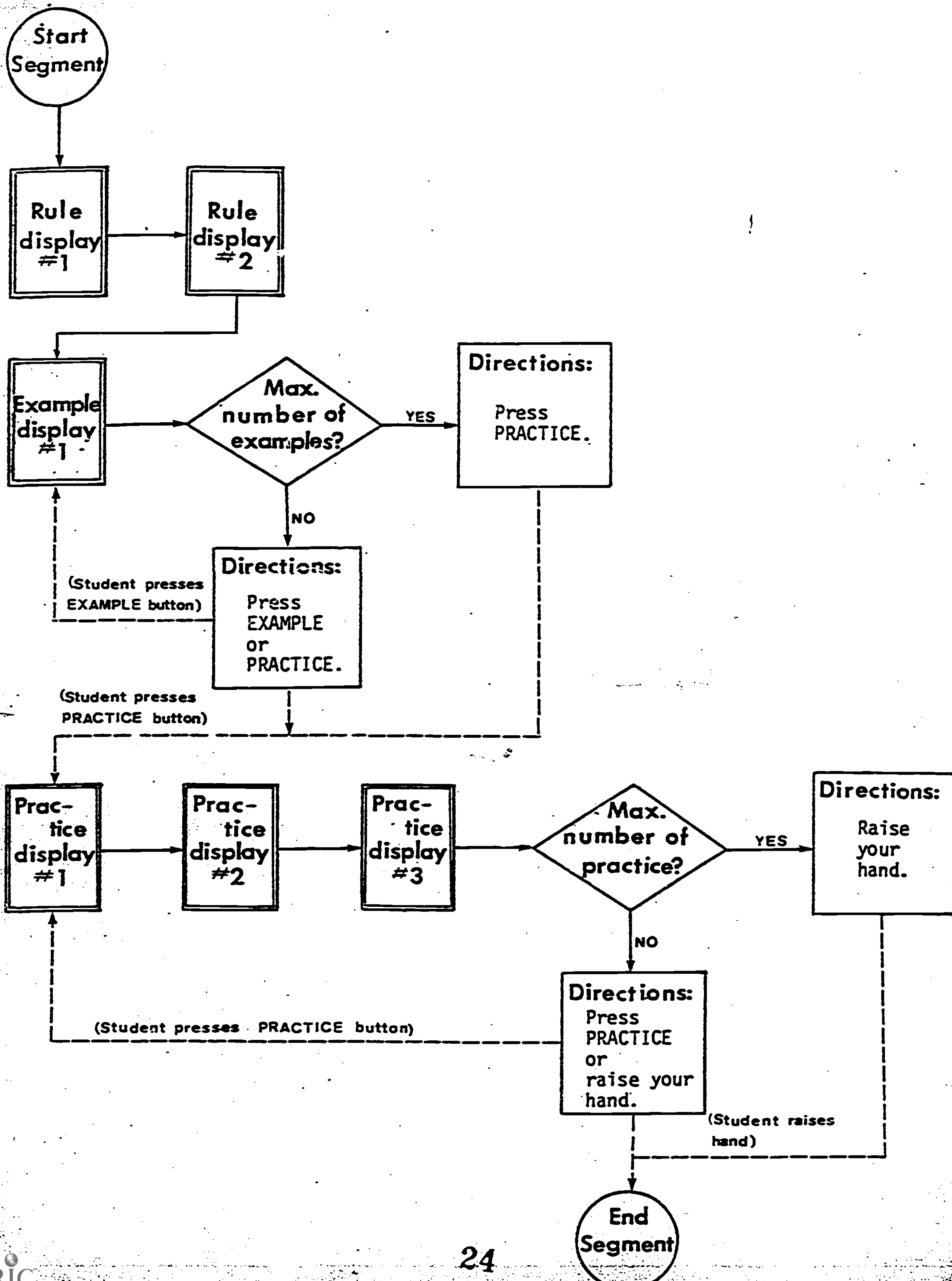
What is log 343?
Given: $343 = 7^3$ $\qquad \log 7 = .8451$

$\log 7^3 = 3 \log 7$

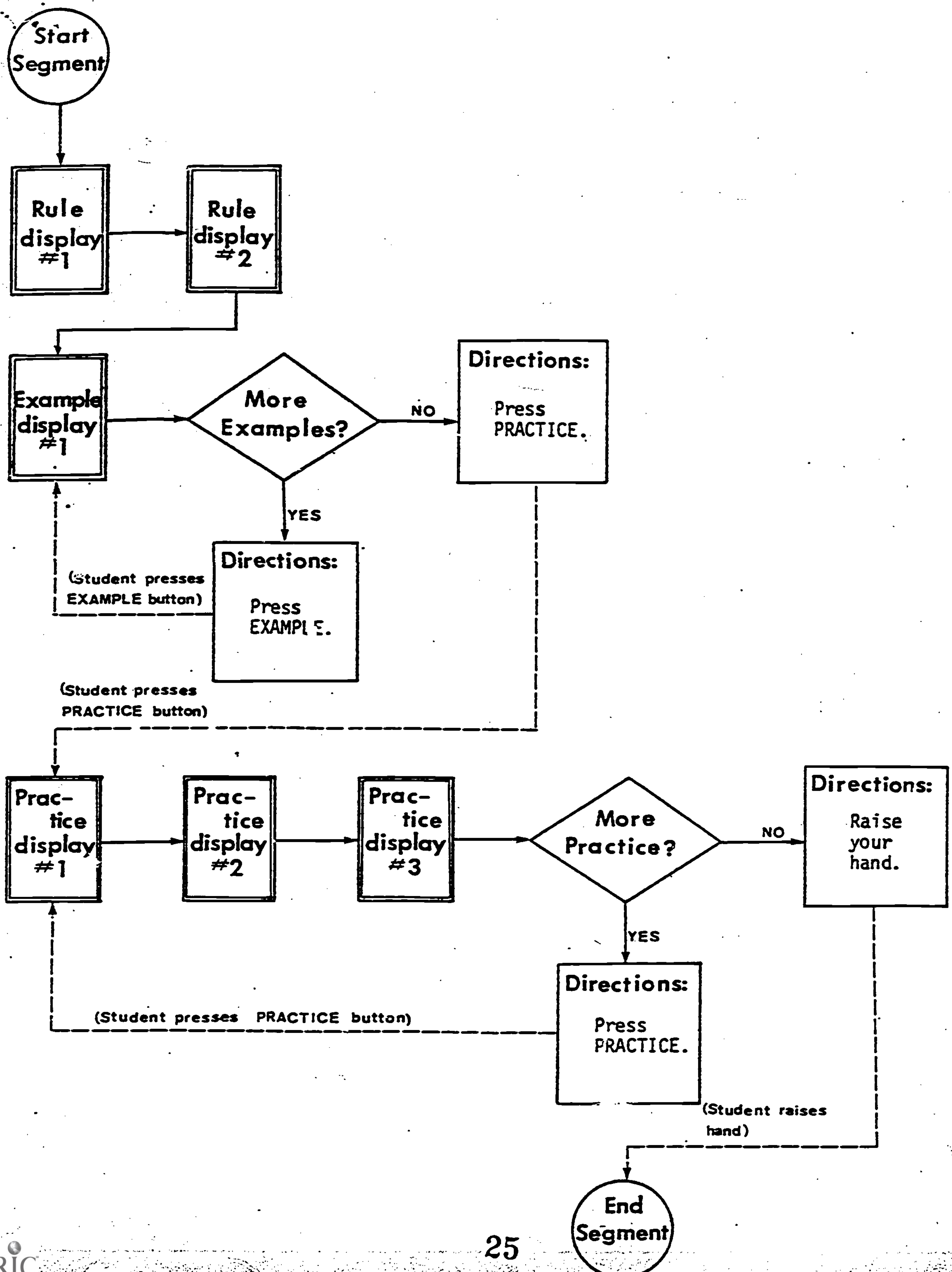
$= 3(.8451)$

$\log 343 = 2.5353$

(student response)



Start Segment
Rule display #1
Rule display #2
Example display #1
Max. number of examples?
YES
Directions:
Press PRACTICE.
NO
Directions:
Press EXAMPLE or PRACTICE.
(Student presses EXAMPLE button)
(Student presses PRACTICE button)
Prac-tice display #1
Prac-tice display #2
Prac-tice display #3
Max. number of practice?
YES
Directions:
Raise your hand.
NO
Directions:
Press PRACTICE or raise your hand.
(Student presses PRACTICE button)
(Student raises hand)
End Segment


Start Segment
Rule display #1
Rule display #2
Example display #1
More Examples?
NO
Directions:
Press PRACTICE.
YES
Directions:
Press EXAMPLE.
(Student presses EXAMPLE button)
(Student presses PRACTICE button)
Prac-tice display #1
Prac-tice display #2
Prac-tice display #3
More Practice?
NO
Directions:
Raise your hand.
YES
Directions:
Press PRACTICE.
(Student presses PRACTICE button)
(Student raises hand)
End Segment